REVIEW OF BASE-STATION ARRAY ANTENNAS DEVELOPED BY UPM

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Abstract.

Several array architectures developed at Universidad Politécnica de Madrid (UPM) for mobile phone and LMDS base station antennas are presented. An eight-element array and multi-beam antennas with enhanced bandwidth have been demonstrated for GSM-UMTS. A practical implementation of a smart antenna with interference cancellation has been built for a 3er generation mobile communication system based on W-CDMA. Low-cost omnidirectional and sectored antennas has been developed for LMDS base station at 3 GHz. A folded three-layer printed reflectarray with shaped pattern has been demonstrated for sector LMDS base stations at 26 GHz.

1. Introduction

Patch array technology has been applied for many years to base station antennas in mobile communications systems, due to their well known characteristics of low-profile, low cost, reliability and flexibility to achieve contoured beams. The pattern requirements for a base station antenna are normally a sector pattern in azimuth and a cosecant squared shape in elevation, which are easily obtained with a passive linear array appropriated excited by a corporate feeding network [1]. More recently, different array architectures have been proposed for base-station antennas in order to improve the system performances by increasing channel capacity, extending range coverage, reducing multipath fading and co-channel interferences [2][3][4], that can be grouped in the so called “smart antennas”. Research on antenna design has been focused on developing new radiating elements and array architectures in order to fulfil the each time more stringent requirements of the system. Radiating elements must provide enough bandwidth, low levels of cross-polarisation and back radiation, high efficiency and power handling. The array architecture can be designed to provide beam shaping, space diversity, polarization diversity, multiple beams in azimuth in order to subdivide a sector and increase the channel capacity, or adaptive radiation patterns in order to eliminate co-channel interferences.

Several array architectures have been developed at Universidad Politécnica de Madrid (UPM) for base station antennas in the different bands of mobile phones (GSM, PCS or UMTS) and Local Multipoint Distribution System (LMDS). This paper describes briefly the various technologies and the improvements demonstrated by UPM for base-station antennas.

2. Eight-element array for GSM-UMTS base station

A planar wideband radiating element has been developed. This element consists of two stacked patches fed by a microstrip line by means of a slot on the ground plane. The material used to implement the microstrip is a high quality PTFE based RF substrate. However the patches are not etched over typical substrate material, but directly printed on the spacer material, which is a low-cost, low-loss expanded PVC with a DK value of 1.7. Using very low DK material yields to higher bandwidths but increases the mutual coupling between elements when they are used in arrays. Therefore, DK equal to 1.7 has been chosen as a trade-off for coupling reduction and bandwidth improvement.

An eight elements array with this architecture has been manufactured, see Fig.1. The measured return losses for each element in the working band (1.71 GHz – 2.17 GHz) are typically better than –18 dB, and the coupling value better than –21 dB. The elements are connected to a corporate feed network, which was designed to enhance bandwidth using two-stage maximally-flat impedance transformers. The amplitude and phase distributions have been designed to obtain a squared cosecant pattern with null filling and upper lobes suppression. Fig.2 shows the measured elevation radiation patterns at several frequencies. The measured return losses for the complete antenna is better than –21 dB.

In conclusion, a planar wide band antenna for GSM-UMTS base stations has been designed, manufactured and tested. The most important drawbacks of using planar antennas, such us low bandwidth, high coupling between elements and etching cost have been addressed in such way that a practical product with excellent performances has been obtained.

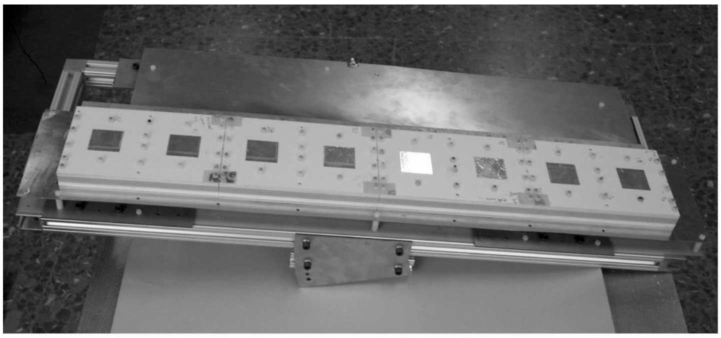

Fig.1. Eight-element array for GSM-UMTS base station.

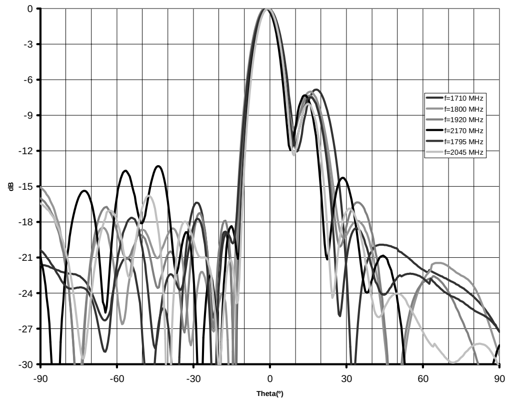

Fig.2. Elevation antenna radiation patterns.

3. Multi-beam array for GSM-UMTS base station

In order to connect four eight-element arrays to build an antenna with four beams in azimuth, a Butler matrix was designed, manufactured and tested using three-branch periodic couplers for bandwidth enhancement, see Fig.3. The measured return losses in all the input ports is better than –17dB, and beam squint in azimuth less than 2.7º in the frequency band 1.74-2.14 GHz. The independent simultaneous beams can be used as electronically selectable beam by placing in the input ports a SP4T controlled by two bit logic.

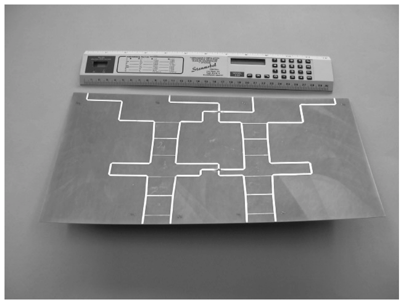

Fig.3. Enhanced band 4x4 Butler matrix

4. Adaptive antennas for GSM-UMTS base station

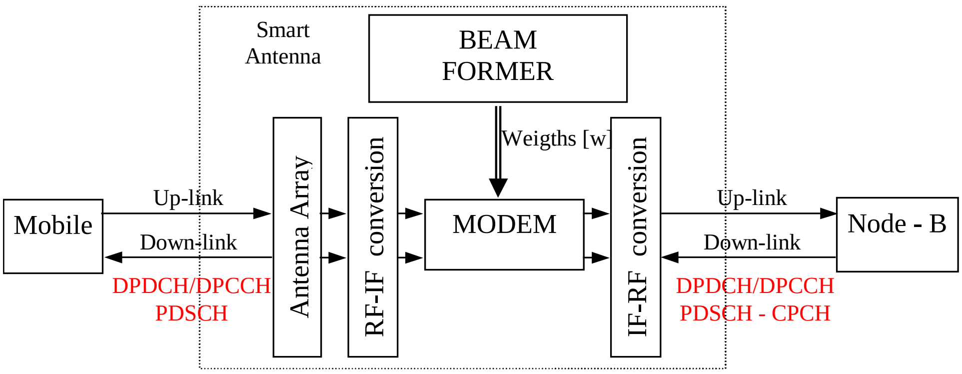

Fig.4. Implementation architecture of our smart antenna to be deployed with a standard Node-B.

A practical implementation of a smart antenna has been built for a 3er generation mobile communication system based on W-CDMA, that is to say, those called UMTS [5]. What is more, the implementation is being done requiring an easy deployment over any base station none specifically developed to be used with a smart antenna [6]. The implemented architecture [7] of our smart antenna can be shown in Fig.4. At down-link, Node-B signal is down-converted from RF to IF, demodulated, shaped (with a set of different weights for each user) and finally up-converted to RF. At up-link an equivalent process is performed but with common weights for all the users. This architecture performs a total interference cancellation in the down-link but only a partial cancellation of only cell external interference for the up-link.

The implemented prototype produces 120º sector coverage and it is built with an array of four standard sectored antennas in UMTS band. Fig.5 shows the general scheme of the transmitter. The combiner allows the usage of several block frequencies. The receiver is a dual scheme.

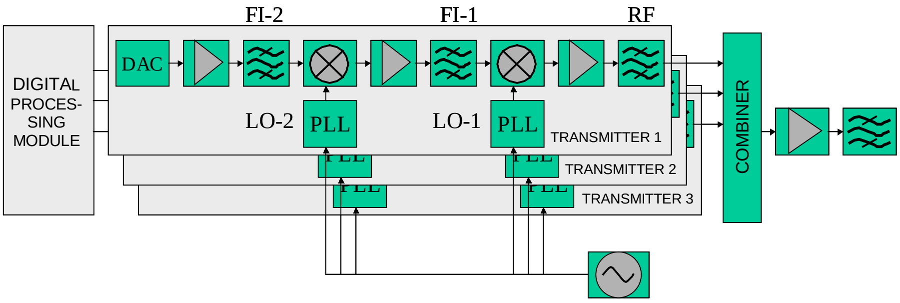

Fig.5. General block scheme of RF-IF stages of transmitter antenna

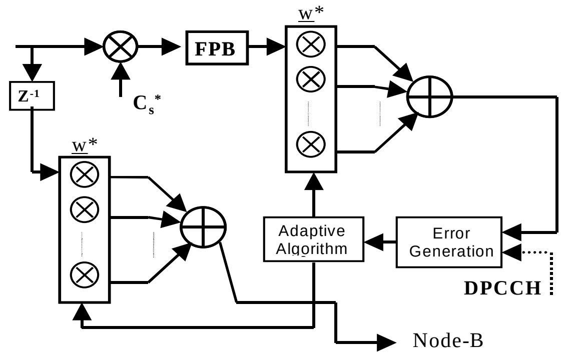

Fig.6. Adaptive process with despread reference signal (Cs*: conjugated of user scrambling code).

The beamformer has been implemented by means of a despread reference at bit and rate level. A block description of shaping process is shown in Fig.6. The spread factor of control channel is 256, so a control symbol is produced each 256 chips. This work justify the feasibility of a realistic implementation of an smart antenna, of adaptive type, applied to an UMTS mobile system and built under the requirement to be compatible with an standard Node B. Lately new beamforming algorithms has been tested based on p.e. neural networks [9] to improve base station performance as ΔC/I respect to sectorial antenna.

5. Central station antenna for LMDS at 3 GHz

Several prototypes of omnidirectional and sector antennas have been designed built and measured for LMDS system, working in the frequency band of 3400 to 3600 MHz and vertical polarisation. The design goal is to get low cost antennas with an omnidirectional and sectored diagram in the normal plane to the antenna axis, and a gain, depending on the antenna model, between 6 and 12 dB. The transmission line used to feed the antenna, is a symmetric stripline made with a 35 microns cooper line between two aluminium sheet distanced 7.5 mm.

The basic dielectric material is made with two plates of expanded polystyrene of 3.7 mm width. In the middle of the two plates, a 125 microns polyester sheet supports the printed cooper circuit. Two face to face printed patches form the elemental brick of the omnidirectional collinear antenna. Patches are printed on conventional 1.5 mm epoxy-glass substrate and placed at H=10 mm from the ground planes. The design of three patches printed radiator coupled to the line through a resonant slot, has allowed a ripple reduction in the omnidirectional plane to ±1.5 dB, keeping a wide feeding stripline structure. For sector antennas, the same feeding structure was used for 60, 90 and 120 degrees beamwidth.

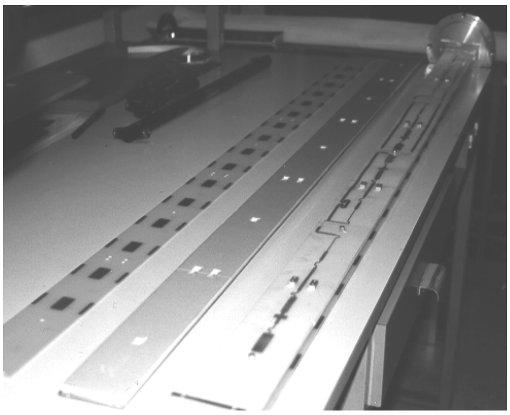

Fig.7. Pieces of collinear antenna for LMDS.

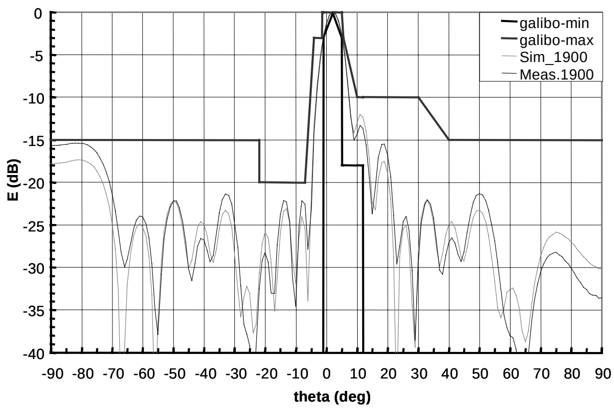

Fig.8. Radiation pattern of 12 element PCS antenna.

6. Printed patch PCS base station antenna.

Twelve element PCS base station antennas have been developed for Rymsa S.A. Radiating patches are built in conventional microwave Teflon-glass substrates and printed microstrip feeding circuits are also printed in the same substrate. Single vertical polarization and dual polarization (±45º) have been developed and prototyping. Fig.8 shows the specified and measured diagram in the vertical plane.

7. Printed reflectarray for LMDS central station sector antenna at 26 GHz

A folded three-layer printed reflectarray with shaped pattern has been developed in collaboration with University of Ulm for sector LMDS base stations at 26 GHz [8]. The pattern requirements are a cosecant squared beam in elevation and a sector beam in azimuth. Fig.9 shows the breadboard, with a polarizing grid, a three-layer microstrip reflectarray to improve bandwidth and a feed embedded in the center of the reflectarray. Folded microstrip reflectarrays have been successfully demonstrated at University of Ulm [10]. The patch axes of the array are tilted by 45° with respect to the incident electric field. The dimensions of the patches are optimized to produce the required shaped pattern in the band 24.5-26.5 GHz, and to keep a phase difference of 180° between the two field components. Therefore, the reflected field is twisted 90º and can pass through the polarizing structure in front of the antenna. In addition, cross-polarisation is significantly reduced by the polarizing grid. Fig.10 shows the 3D measured pattern at 25 GHz, that agrees well with pattern requirements. This technology allows to achieve the required pattern by simply optimising the dimensions of printed patches.

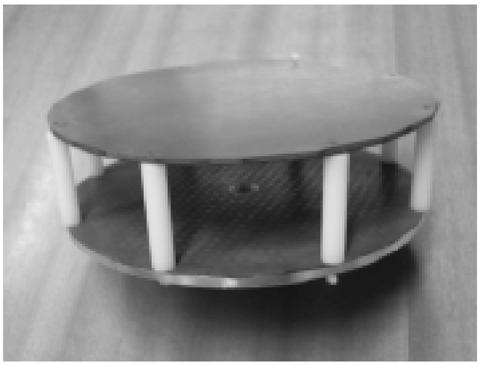

Fig.9. Picture of the manufactured folded 3-layer reflectarray with shaped pattern.

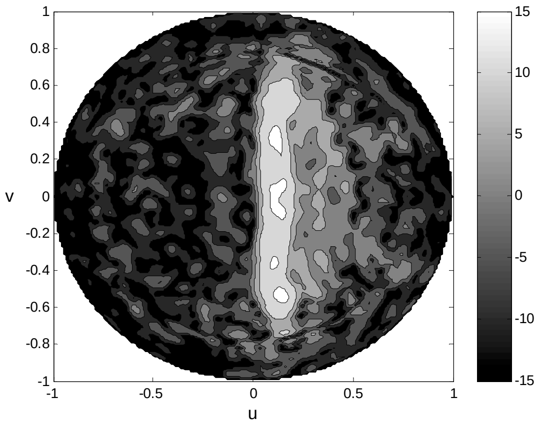

Fig.10.3D measured gain radiation pattern at 25 GHz.

8. Conclusions

Design, manufacture and measurements of several prototypes have been performed at UPM for base station antennas in the different bands of GSM, PCS, UMTS and LMDS systems. Some improvements have been demonstrated in the proposed architectures, such as low-cost, bandwidth enhancement, beam shaping or interference cancellation.

9. References

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